

An Empirical Perspective on the Energy Payback Time for Photovoltaic Modules

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SOLAR 2000 Conference

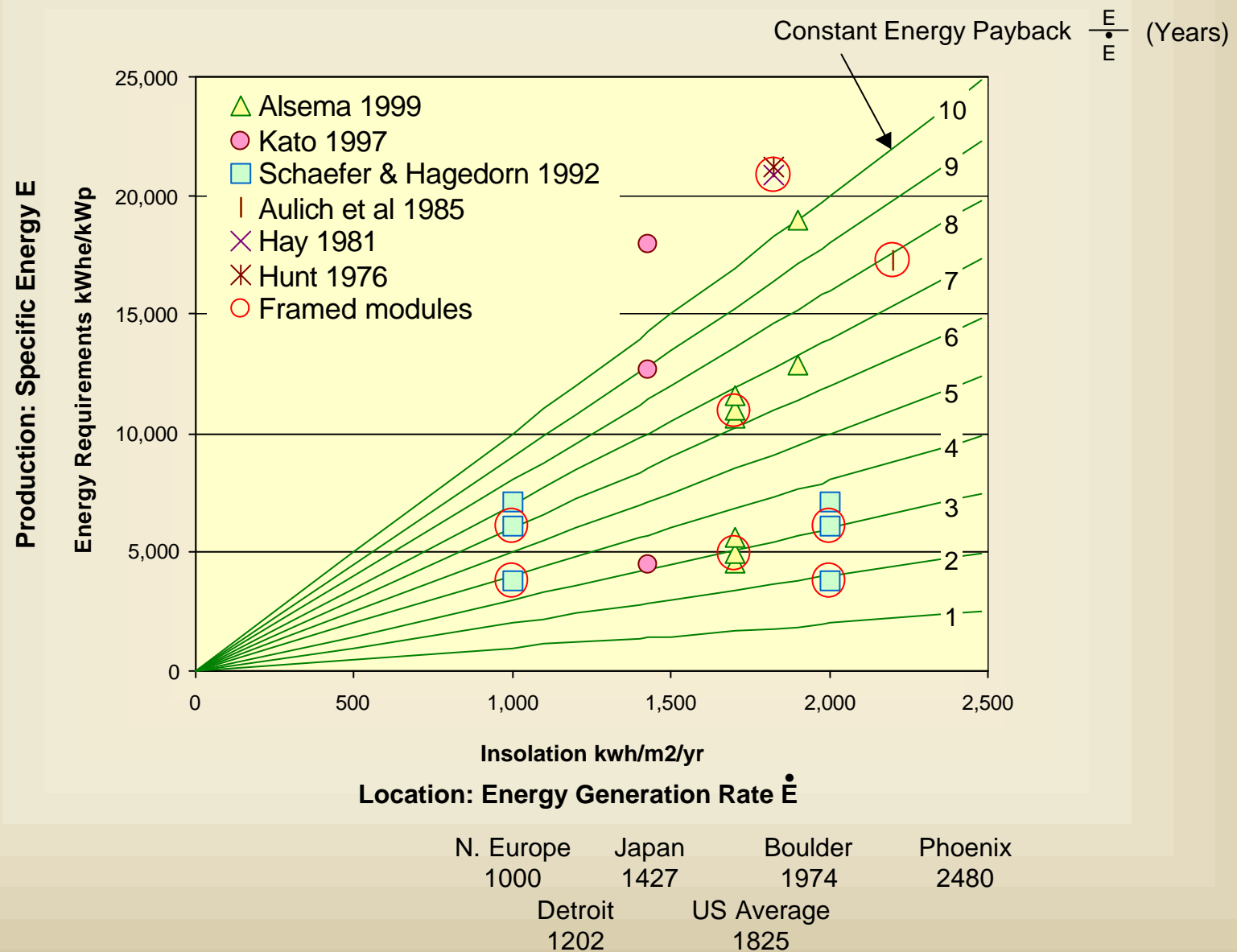
June 16-21, 2000

Madison, Wisconsin

Overview

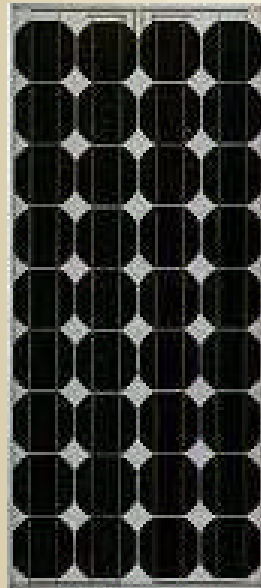
- Energy payback determinants
- Methodology
- Process energy results
- Materials embodied energy results
- Energy payback time results
- Prospects

Energy Payback Depends on PRODUCTION and LOCATION



Two significantly different products were evaluated.

Single-Crystal Silicon



sc-Si
SP75

Polysilicon Preparation
Crystal Growing
Ingot Shaping

Ingot

Ingot Sizing
Mounting
Wire Saw Cutting
Cleaning
Chemical Etching
Phosphorous Diffusion
Post Diffusion Etch
Oxidation
Plasma Etch
Anti Reflective Coating
Front Print
Back Print
Cell Test
Packaging

Wafer/ Cell

Cut Glass\
Wash / Deposit Mo Electrode
Pattern 1: Isolation
Wash / Deposit CIG Metals
Selenize
Chemical Deposit CdS
Pattern 2: Via
Transparent Conductor
Pattern 3: Isolation
Test

Stringing
Circuit Assembly
Prelamination Lay-up
Lamination & Cure
Edge Trim & Inspection
Framing
IV Measurement & Labeling
Packaging

Module

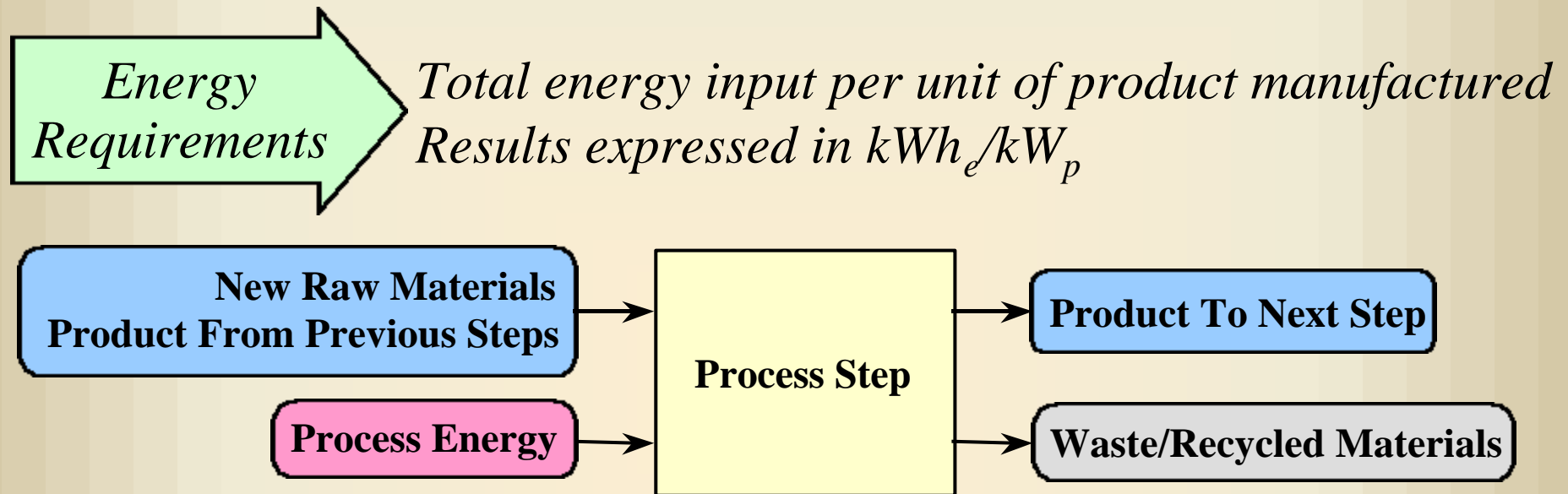
Attach Leads
Prelamination Lay-up
Lamination & Cure
Framing
Edge Trim & Inspection
IV Measurement & Labeling
Packaging

Thin-Film Copper Indium Diselenide



CIS
ST40

Analysis uses measured energy use, production bill of materials, and production records.



•Includes

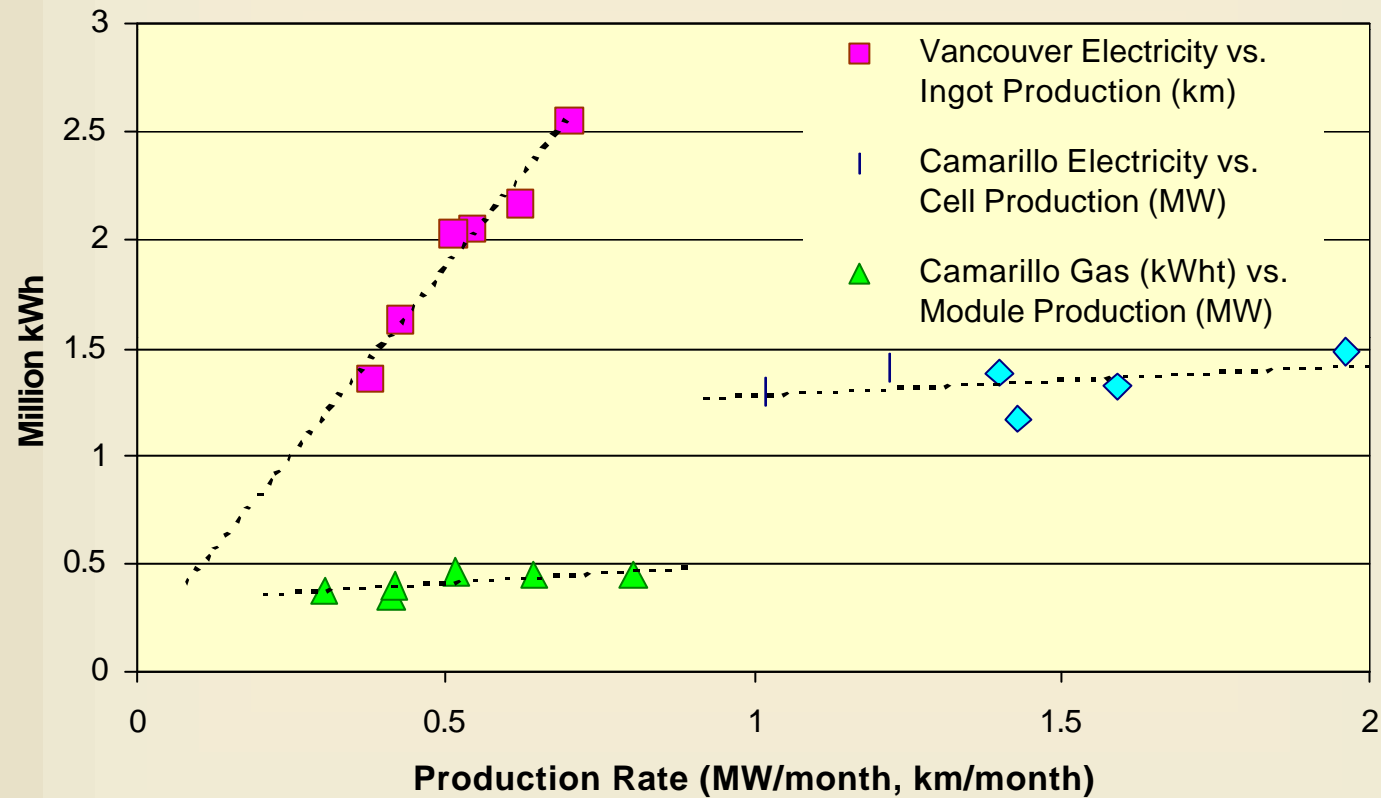
- All added process energy
- All direct AND indirect materials
- Required upstream processes

•Does not include

- Energy embodied in facility
- Labor equivalent
- Transportation
- End-of-life
- Unnecessary upstream energy

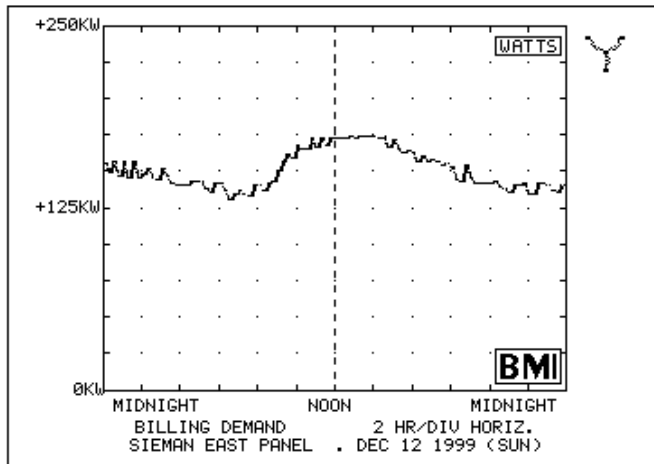


sc-Si process energy requirements derived from production records and utility bills.



CIS process energy requirements derived from direct measurements, equipment ratings, and production records.

SIEMAN EAST PANEL . Dec 13 1999 (Mon)
BILLING DEMAND 12:00:11 AM
FROM: MIDNIGHT Dec 11 1999 (Sat)
To: MIDNIGHT Dec 12 1999 (Sun)
DEMAND INTERVAL: 15 min
SLIDING INTERVAL: No
Total:
MAX: 175.1 kW, 12:57 PM
MIN: 131.6 kW, 6:42 AM
Phase A-N:
MAX: 59.1 kW, 2:12 PM
MIN: 45.3 kW, 6:42 AM
Phase B-N:
MAX: 55.6 kW, 12:57 PM
MIN: 40.5 kW, 6:42 AM
Phase C-N:
MAX: 60.5 kW, 12:57 PM
MIN: 45.9 kW, 6:42 AM



BILLING DEMAND (ACCUMULATED):
MAX: 296.8 kW
3:14 PM Dec 09 1999 (Thu)
MIN: 131.6 kW
6:42 AM Dec 12 1999 (Sun)

Process
Energy

Measured

Estimated at
measured rates

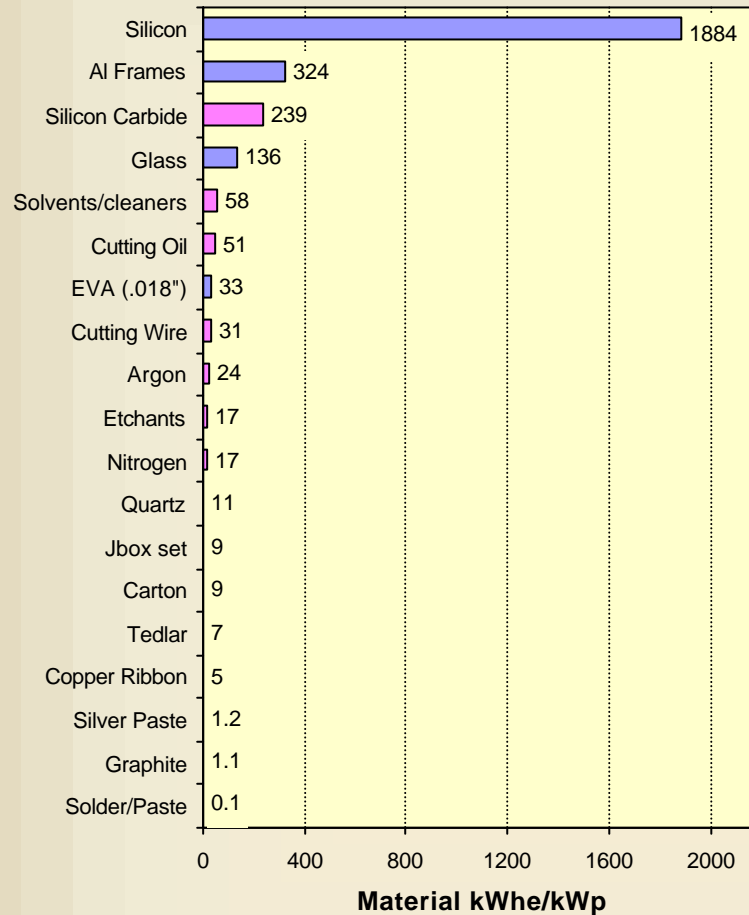
15

200

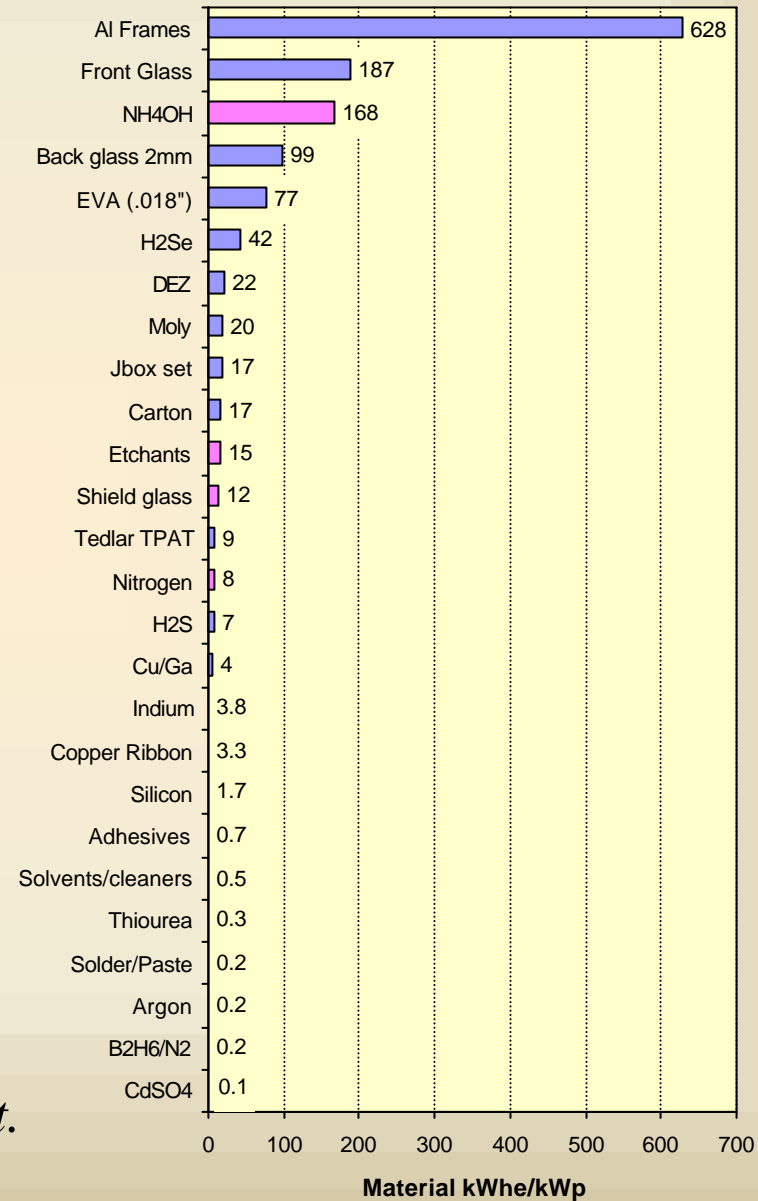
Production Rate kWp/month

Materials embodied energy is about half of total.

SP75: Total = 2857 Material (2742 Process)

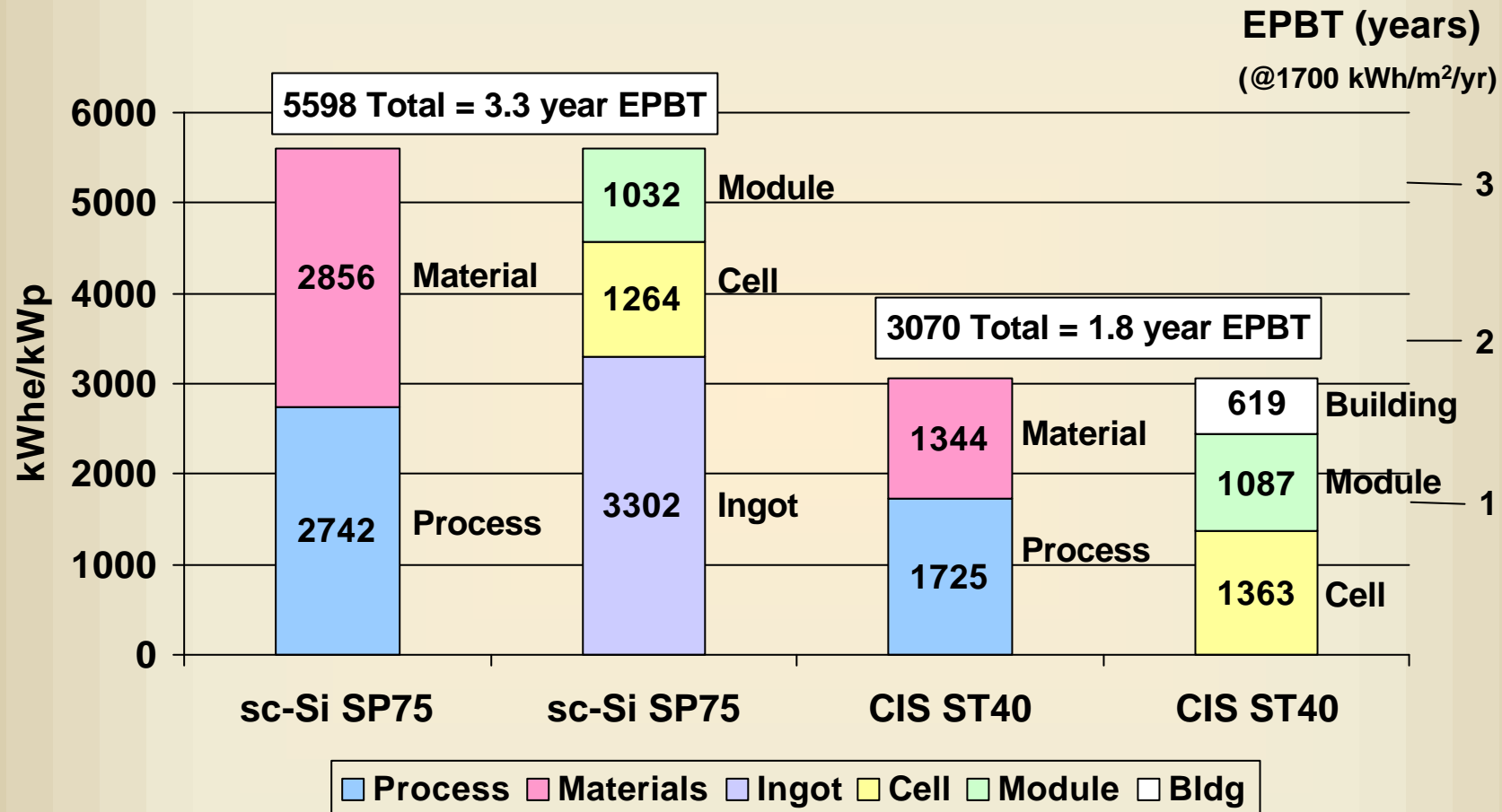


ST40: Total = 1345 Materials (1725 Process)

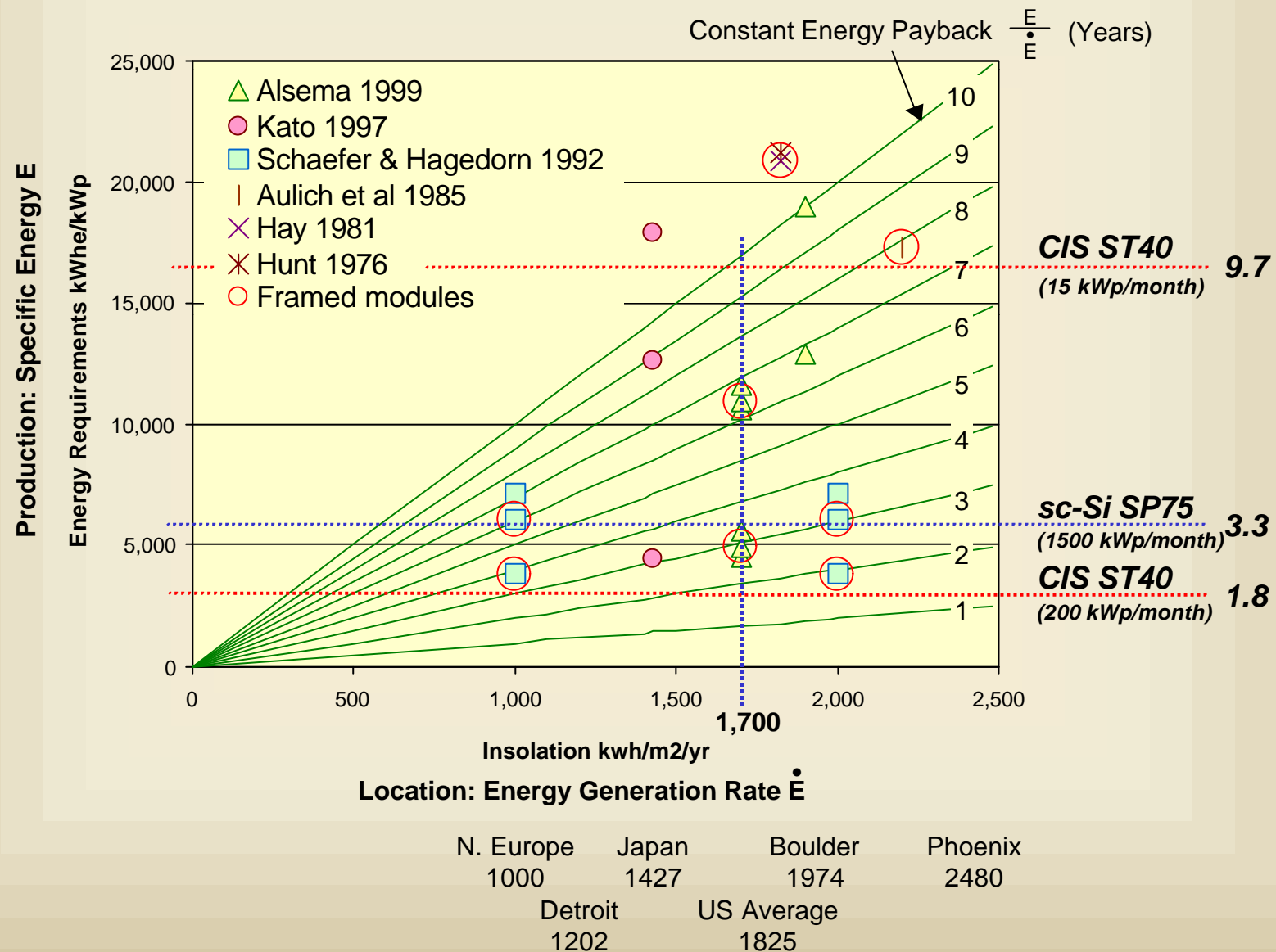


- ➡ *Materials energy dominated by a few big-ticket items.*
- ➡ *Indirect materials can be significant.*

Production photovoltaic module payback is much less than its expected lifetime.



Results provide empirical support for other analytical methods.





Conclusions, Notes & Prospects



- Production photovoltaic module payback is significantly less than its expected lifetime.
 - Payback time is 2-3 years.
 - Energy output is nine to seventeen times the input.
 - Indirect materials are important
 - Results lend empirical support for related research.
- Most other energy requirements are relatively small.
 - Equipment, building, labor equivalent
 - Balance of systems requirements can be significant.
- Energy intensity improvements driven by cost issues.
 - Yield, lower materials use and cost
 - Innovative processing and product design
- Prospects for reduced energy requirements are likely.



END